B2

PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :
F23G 7/06, B01J 19/08

A1

(11) International Publication Number: WO 95/06225

(43) International Publication Date: 2 March 1995 (02.03.95)

(21) International Application Number: PCT/GB94/01818

(22) International Filing Date: 19 August 1994 (19.08.94)

(30) Priority Data:
9317389.6 20 August 1993 (20.08.93) GB

(71) Applicant (*for all designated States except US*): BRITISH TECHNOLOGY GROUP LIMITED [GB/GB]; 101 Newington Causeway, London SE1 6BU (GB).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): HARRY, John, Ernest [GB/GB]; Greenlands, Knossington Road, Braunston, Oakham, Leicestershire LE15 8QX (GB).

(74) Agent: DAVIS, Norman, Norbridge; British Technology Group Limited, Patents Dept., 101 Newington Causeway, London SE1 6BU (GB).

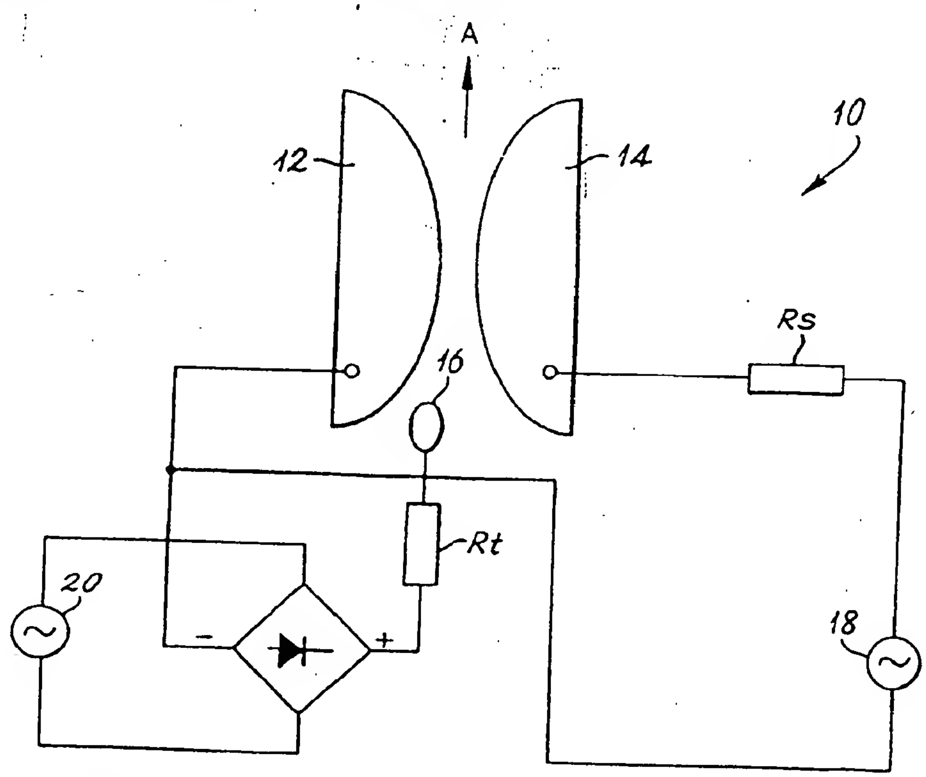
(81) Designated States: GB, JP, US, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: IMPROVEMENTS IN REMOVAL OF NOXIOUS GASES FROM EMISSIONS

(57) Abstract

The invention relates to apparatus for removal of noxious gases from emissions, such as volatile organic compounds (VOC's). Existing arrangements for reduction of VOC's comprise two electrodes in the form of tapered flat surfaces having a potential difference applied across them. Gas containing VOC's passes between the electrodes and VOC's when detected, were incinerated in the discharge, leaving less harmless end products. A disadvantage with the aforementioned arrangements was that the reactive power requirement was extremely high. This was due to the initial striking voltage required to cause discharge being of the order of several tens of kilowatts at atmospheric pressure. The present invention employs an auxiliary electrode (16) positioned between two electrodes (12 and 14) and control circuitry (18, 20, R_s and R_t) arranged to substantially reduce the initial striking voltage and therefore the complexity, power consumption and maximum power capability of the apparatus.



FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	GB	United Kingdom	MR	Mauritania
AU	Australia	GE	Georgia	MW	Malawi
BB	Barbados	GN	Guinea	NE	Niger
BE	Belgium	GR	Greece	NL	Netherlands
BF	Burkina Faso	HU	Hungary	NO	Norway
BG	Bulgaria	IE	Ireland	NZ	New Zealand
BJ	Benin	IT	Italy	PL	Poland
BR	Brazil	JP	Japan	PT	Portugal
BY	Belarus	KE	Kenya	RO	Romania
CA	Canada	KG	Kyrgystan	RU	Russian Federation
CF	Central African Republic	KP	Democratic People's Republic of Korea	SD	Sudan
CG	Congo	KR	Republic of Korea	SE	Sweden
CH	Switzerland	KZ	Kazakhstan	SI	Slovenia
CI	Côte d'Ivoire	LI	Liechtenstein	SK	Slovakia
CM	Cameroon	LK	Sri Lanka	SN	Senegal
CN	China	LU	Luxembourg	TD	Chad
CS	Czechoslovakia	LV	Latvia	TG	Togo
CZ	Czech Republic	MC	Monaco	TJ	Tajikistan
DE	Germany	MD	Republic of Moldova	TT	Trinidad and Tobago
DK	Denmark	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	US	United States of America
FI	Finland	MN	Mongolia	UZ	Uzbekistan
FR	France			VN	Viet Nam
GA	Gabon				

IMPROVEMENTS IN REMOVAL OF NOXIOUS GASES FROM EMISSIONS

This invention relates to improvements in removal of noxious gases and more particularly, but not exclusively, to improvements in apparatus for the oxidation of Volatile Organic Compounds (VOCs).

The disposal of hazardous waste and toxic materials has advanced considerably from the use of uncontrolled landfill. Developments have come about as a result of increasingly restrictive legislation that requires many forms of waste to be pretreated often by incineration. As a result incinerators have grown in complexity.

The problem has been exacerbated by the increasing use of chlorinated plastics producing dioxins, the growing awareness of the hazards and the public perception of even quite harmless emissions. The rise in both capital cost and running cost of improving existing methods and ever increasing legislation are favourable for the introduction of new processes using electric discharges as an alternative to conventional processes. Electric discharges are already used for vitrification of hazardous materials and for reclaiming heavy metals from metallurgical flue dust as an alternative to disposal by landfill.

Advantages obtainable by using electric discharges for oxidising VOCs include: higher temperature and energy densities than combustion processes, alternative chemical routes; and greater conversion efficiencies where selective chemical transitions can be carried out.

Electric discharges can be used for the synthesis or destruction of chemical compounds in many ways using the different energy transition processes involved in the release of the potential energy over their different ranges of operation.

An arrangement which incinerates VOCs is described in published French Patent Application No. FR-A-9011278 in the name of SOCIETE GIENNOISE DE MECANIQUE ET DE METALLURGIE SA. The

arrangement extracts fumes from a spray paint workshop and incinerates the noxious fumes to produce relatively harmless products.

The incinerator comprises two electrodes which were effectively knife-blades, the distance between whose tapered edges varied smoothly. A potential difference was established across the electrodes and a region of an igniting portion of gas progressed in a longitudinal direction, between the electrodes.

Another device for incinerating VOCs is described in European Patent Application No. EP-A-91120941.9, which is in the name of ON-DEMAND ENVIRONMENTAL SYSTEMS INC. This describes an incinerator which is designed to be retro-fitted into an existing exhaust airstream. A detector is present which detects VOCs and turns on the incinerator when required.

AC discharge devices suffered from a number of drawbacks and in particular their reactive power requirements were high as the initial striking voltage required to cause discharge ignition was high. One reason for this is because processing material in the vapour or gas phase requires operation at or close to atmospheric pressure and high power, of the order of several tens or hundreds of kW to achieve a useful throughput.

Reliable breakdown between electrodes in flowing air at atmospheric pressure, such as those flow speeds used in the VOC incineration process, has required an electric field strength of at least 3kV/mm in air. However, in some gases this value will be exceeded. The high ratio of open circuit voltage (V_{OC}) to the arc voltage results in poor utilisation of the power supply, in that the reactive power is much greater than the power. Use of the third or auxiliary electrode and a separate high voltage low current ignition supply allows the voltage between the first and second, primary, electrodes to be increased by increasing the electrode separation. Alternatively the open circuit voltage can be decreased to less than half of its value for existing arrangements.

Thus existing equipment has been required to have high reactive power capabilities, even though it was not always required to operate at these maximum powers. Furthermore after ignition had been achieved it was not necessary to have such large potential differences appearing across electrodes as such high levels of reactive power dissipation were undesirable. Alternative approaches used complex electrodes which were water cooled and expensive or expensive secondary electrical switchgear for changing conditions following ignition of the gas(es).

These factors have generally limited the useful range of electric discharges to glow or corona and arc discharge for industrial scale application. The present invention aims to obviate these and other problems and seeks to provide an arrangement which requires less reactive power and is therefore cheaper.

According to a first aspect of the present invention there is provided apparatus for producing an electric arc comprising a first and a second electrode and means for establishing a potential difference across the two electrodes; a third or auxiliary electrode, means for applying a potential difference between the third or auxiliary electrode and at least one of the first and second electrodes such that the voltage required to achieve breakdown across the first and second electrodes is reduced.

Preferably the breakdown voltage is reduced by at least one half of its previous value. Advantageously the apparatus is fitted into an incinerator and burns noxious products such as VOCs.

Preferably the third or auxiliary electrode is positioned such that it is offset between the first and second electrodes. That is it is closer to the first electrode than to the second electrode. Advantageously the first and second electrodes have a larger surface area than the third electrode and they are dimensioned and arranged such that gas flows between a volume

whose envelope is partially determined by the slope of the surface of each electrode.

The first and second electrodes may have surfaces which are curved in one or more planes, such that they form sloped portions of arcuate bounded laminae or portions of spherical or ovaloid bodies. Preferably however the electrodes are of relatively simple shapes which may be readily punched or stamped from metal sheets. This ensures the electrodes are cheap.

Occasionally electrodes may need replacing as inevitably some corrosion occurs. However, it is felt the benefit of relatively cheap costs of electrodes and ease of replacement far outweighs the expense of complex electronic switchgear and/or electrode cooling equipment which has heretofore been required.

According to another aspect of the present invention there is provided an auxiliary electrode adapted for insertion into an incinerator which is equipped with a first and second electrode, the auxiliary electrode having a power supply and being dimensioned and arranged with respect to the first and second electrodes such that voltage required across the first and second electrodes to achieve breakdown is reduced.

It will be appreciated that the arrangement in accordance with the second aspect may be retro fitted to existing equipment. Similarly two or more auxiliary electrodes may be fitted.

The positioning of the third, fourth or higher order, auxiliary electrode is not crucial, but it should be such as to assist breakdown between the main electrodes to occur. The establishment of a discharge emission site greatly increases effectiveness of operation and enables a lower breakdown voltage between the electrodes.

In one arrangement, described below, a low current of approximately 0.1 A supplies the third electrode. Current is derived from an independent supply from that used to supply the primary electrodes. However, suitable transforming may be

provided such that a single electrical supply may be used.

Preferably there are two electrical supplies one being higher than the other typically by an order of about two. A fullwave bridge rectifier may be used to supply the third, or auxiliary electrode. In an alternative embodiment a fourth, auxiliary, electrode may be connected to opposite arms of the bridge rectifier such that odd numbered half-cycles are applied to the third electrode and even numbered half cycles are applied to the fourth electrode (or vice versa).

Typically the power consumption of the auxiliary electrode driver circuit is less than 1kW and preferably less than 500W. The saving this auxiliary circuit makes on the overall reactive power consumption of the device is considerable despite the slight increase in running costs due to increased frequency of electrode replacement.

The first and second electrodes are so dimensioned and arranged as to permit an igniting arc to move across their respective surfaces from a region of narrow gap to a wider gap. This movement is due partially to convection effects and partially to the movement of gas through the narrow region of what may be envisaged as a tapered necked region to a wider region. The term used to described this phenomenon is called "Glydarc".

The advantage of the VOC incineration process depends on its inherent simplicity which requires the use of alternating current and therefore repeated ignition of the discharge to prevent a static discharge forming which would result in erosion of the electrodes. However, in special conditions it may be possible to use a direct current to supply the arrangement.

The voltage breaks down the minimum gap between the electrodes on each half cycle of the supply voltage to form a short low voltage arc. The arc then lengthens and reaches a discharge voltage of nearly 1kV and is largely independent of the electrode separation since the discharge is blown clear from the

electrodes. Even with an electrode gap of 1mm the breakdown voltage is in excess of 3kV in still air and is even higher in a gas flow. As a result a supply voltage above about 5kV is required to ensure reliable ignition on each half cycle voltage. If resistive stabilisation is used the power supply consequently is less than 20% efficient or alternatively if as in practice inductors are used to avoid power loss the equipment operates at a power factor of less than 0.2 i.e. a utilisation of the available power of 20%.

To reduce the ratio of breakdown to operating voltage auxiliary electrodes, or pilot arcs, can be used both with DC and AC devices. However, since a major advantage of the Glydarc process is its inherent simplicity any alteration to the electrode design must be correspondingly simple in order to retain its advantages.

Breakdown of the electrode gap between the primary electrodes can be achieved at a reduced voltage by creating an emission site and/or ionised gas at one electrode with a separate discharge circuit and supply. This is a 3 electrode form of a multiple electrode discharge similar to those used as pilot arcs in transferred arc plasma torches and discharge lamps. The auxiliary discharge may be DC or AC although the use of DC eliminates effects due to variation in the phase angle between the two supplies. Such an arrangement is described in detail below.

The position of the third or auxiliary electrode is critical so as to prevent a conducting path to the main supply to the first and second electrodes, (which has a lower resistance than the electrode gap before breakdown), and it must also be positioned so as to prevent damage to the auxiliary electrode by the main discharge. This is achieved by locating the auxiliary electrode closer to one electrode than the other and can even be offset from the plane of the 2 electrodes.

An embodiment of the present invention will now be described,

by way of an example only, and with reference to the Figures in which:-

Figure 1 is a circuit diagram of a VOC incinerator showing primary and auxiliary electrodes;

Figure 2 shows graphs of discharge voltage against discharge current for different electrode separations;

Figure 3 graphs of discharge voltage against ignition discharge current for different electrode separations; and

Figure 4 is a graph of discharge voltage against separation of primary electrode.

Referring to Figure 1, an incinerator 10 had two primary electrodes 12 and 14 and an auxiliary electrode 16. Electrodes 12 and 14 have a power supply 18. Electrode 14 is connected to power supply 18 via resistor Rs. A diode bridge 22 ensures current is delivered to auxiliary electrode 16 via resistor Rt from power supply 20. Gas to be ignited flows in the direction of arrow A.

A series of tests using the arrangement in Figure 1 were carried out to determine the effectiveness of auxiliary ignition electrode 16 on increasing the arc voltage across electrodes 12 and 14 by enabling a greater separation between the main discharge electrodes 12 and 14 or on reducing the minimum electrode voltage.

Tests were carried out over a range of air flow rates of 5-10 l/min. Corresponding to an air velocity at the nozzle outlet of 24-48m/s.

The discharge current is almost sinusoidal and repetitive and was measured with an analogue meter. The discharge voltage is very non sinusoidal and non repetitive with large extinction and ignition peaks. To overcome this the discharge voltage was derived from the current measurement since

$V_d = V_{oc} - IR_s$

The first series of measurements were made of the discharge voltage and current characteristic across the primary electrodes

(12 and 14) without auxiliary electrode 16 for a separation between the two electrodes (12 and 14) of 1mm and 2mm.

These graphs show only a small increase in discharge voltage with separation between the primary electrodes 12 and 14. This is marked mainly by random variations. This is not surprising since for most of its duration the discharge is extended many times the electrode (12 and 14) separation by the gas flow. The increase in voltage with current is contrary to the normal behaviour of a discharge, however as the current increases the discharge tends to become more stable and a longer discharge could be sustained before extinction occurred.

The variation of auxiliary discharge voltage with current (auxiliary discharge characteristic) was measured and the results are seen in Figure 3.

Figure 3 shows dependence of discharge current (Ig) on voltage (Vg). At different electrode (12 and 14) separations with the auxiliary electrode 16 connected as anode. The discharge was unstable at about 6 mm and at currents below about 0.08 A. All subsequent tests were carried out at 0.1A with separations over the range 2 mm - 6 mm between the primary and the auxiliary electrodes.

The effect of the auxiliary electrode 16 is shown in Figure 4. The separation between the primary electrodes 12 and 14 could be increased up to 12 mm before the arc no longer ignites. The main discharge voltage was almost independent of the separation of the primary electrodes 12 and 14 which is consistent with the observations at electrode separations of 1 mm and 2 mm without an auxiliary electrode 16 as seen in Figure 2.

Figure 4 shows variation of separation rd with discharge voltage Vd. Tests were carried out to determine the effect of the auxiliary discharge between on the V-I characteristic of the main discharge, Figure 2 for separation of 2 mm and 4 mm of auxiliary electrode from the primary electrode. The results are similar to the discharge characteristic without the ignition

electrode but at a much larger electrode separation and with greater discharge stability. The effect of the separation between the primary electrode and auxiliary electrode was not significant.

A further series of tests at much larger separations of the primary electrodes (Figure 2) at a constant separation between the primary and auxiliary electrode was carried out. Again this is largely independent of the separation between the primary electrodes but the voltage is higher and much more stable. A final test was carried out to determine the minimum voltage at which the discharge would ignite using an auxiliary electrode with and without a gas flow. The operating points for these conditions are shown in Figure 4.

This is illustrated by the decrease in voltage required in one of the experiments, as shown by the point P on the graph in Figure 4, compared with the correspoding points Q1-Q5 at a much higher voltage. The open circuit voltage is only about 2.0kV compared with the normal value of about 5.5kV.

The results show that the primary electrode 12 and 14 separation can be increased by using a third electrode 16 but the arc voltage only increases by a small amount. The results also indicate that the supply voltage can be reduced to less than a half the value previously required, increasing the utilisation and reducing the loss in the power supply. As the separation of the primary electrodes is increased above the minimum value required for ignition, with no auxiliary electrode, the effect on the arc voltage is not so great and the discharge voltage is insensitive to the separation of the auxiliary electrode but increases with discharge current.

It will be appreciated that variation to the embodiment may be made without departing from the scope of the invention. For example a fourth or higher order auxiliary electrode may be installed to a VOC incinerator. Alternatively, or in addition to, a DC biassing voltage may be applied to the third or

auxiliary electrode so as to ensure the required potential difference was present to initiate local ionisation. This biassing voltage may be arranged to follow any variation in the potential difference across the primary electrodes.

It will be appreciated that the invention may be incorporated into an exhaust system of a vehicle. In particular a low-power arrangement may be fitted to the exhaust of a diesel powered vehicle such as an articulated lorry, in order to significantly reduce the exhaust emissions.

CLAIMS

1. Apparatus for producing an electric arc comprising a first and second electrode and means for establishing a potential difference across the two electrodes; a third or auxiliary electrode; means for applying a potential difference between the third or auxiliary electrode and at least one of the first and second electrodes such that the voltage required to achieve breakdown across the first and second electrodes is reduced.

2. Apparatus according to Claim 1 wherein the means for applying a potential difference between the third or auxiliary electrode and at least one of the first and second electrodes achieves a reduction in the breakdown voltage of at least 50% in the same apparatus without the third or auxiliary electrode.

3. Apparatus according to Claim 1 or Claim 2 wherein the third or auxiliary electrode is positioned between the first and second electrodes, but is substantially closer to the first electrode than to the second electrode.

4. Apparatus according to any preceding claim wherein the surface area of the third electrode is less than the surface area of either the first or the second electrodes.

5. Apparatus according to any preceding claim wherein edges of surfaces between the first and second electrodes define blade like edges.

6. Apparatus according to any of Claims 1 to 4 wherein the surfaces of the first and second electrodes are symmetric about an axis and define a pathway for a fluid.

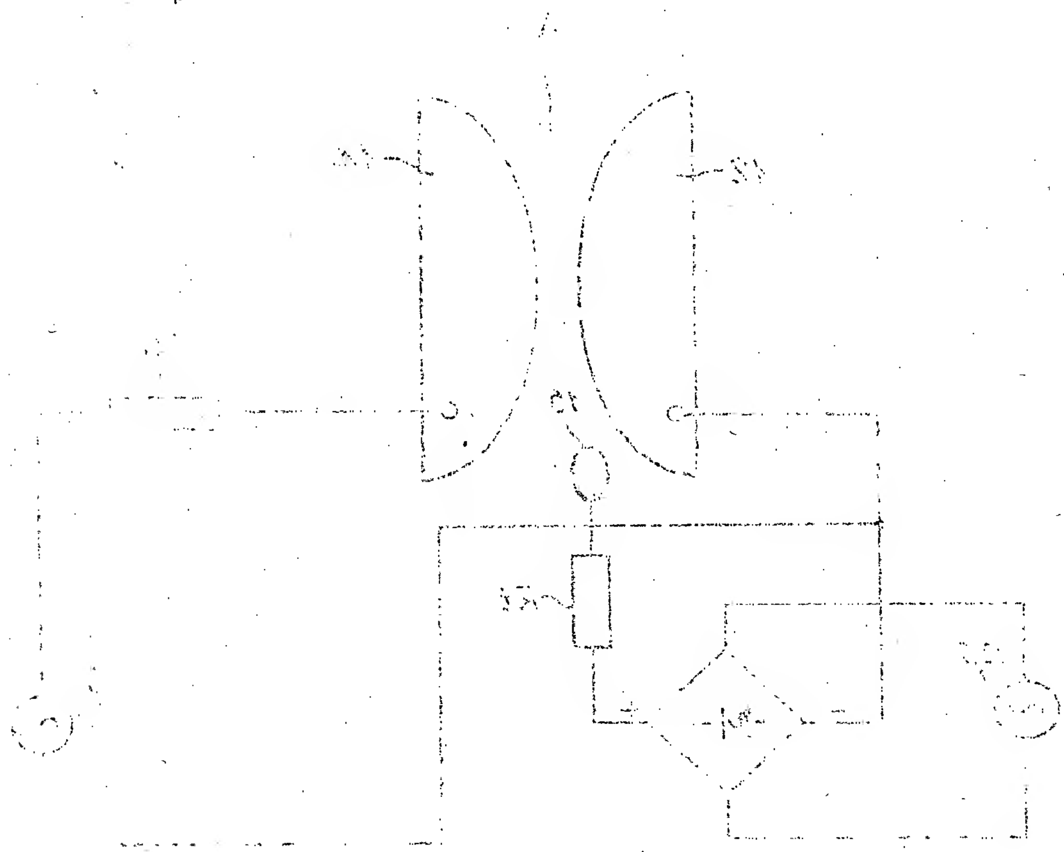
7. Apparatus according to any preceding claim capable of receiving a fourth or higher order auxiliary electrode.

8. Apparatus according to any of Claims 1 to 7 having a power requirement of less than 1 kW and preferably less than 500W.

9. An auxiliary electrode adapted for insertion into an incinerator for incineration of noxious gases, the incinerator having first and second electrodes, the auxiliary electrode having a power supply and being dimensioned and arranged with respect to the first and second electrodes such that voltage

required across the first and second electrodes to achieve breakdown in the gas(es) is reduced.

10. An electrode according to any preceding claim in which a current is supplied at a value substantially at or less than 0.1 Amp.



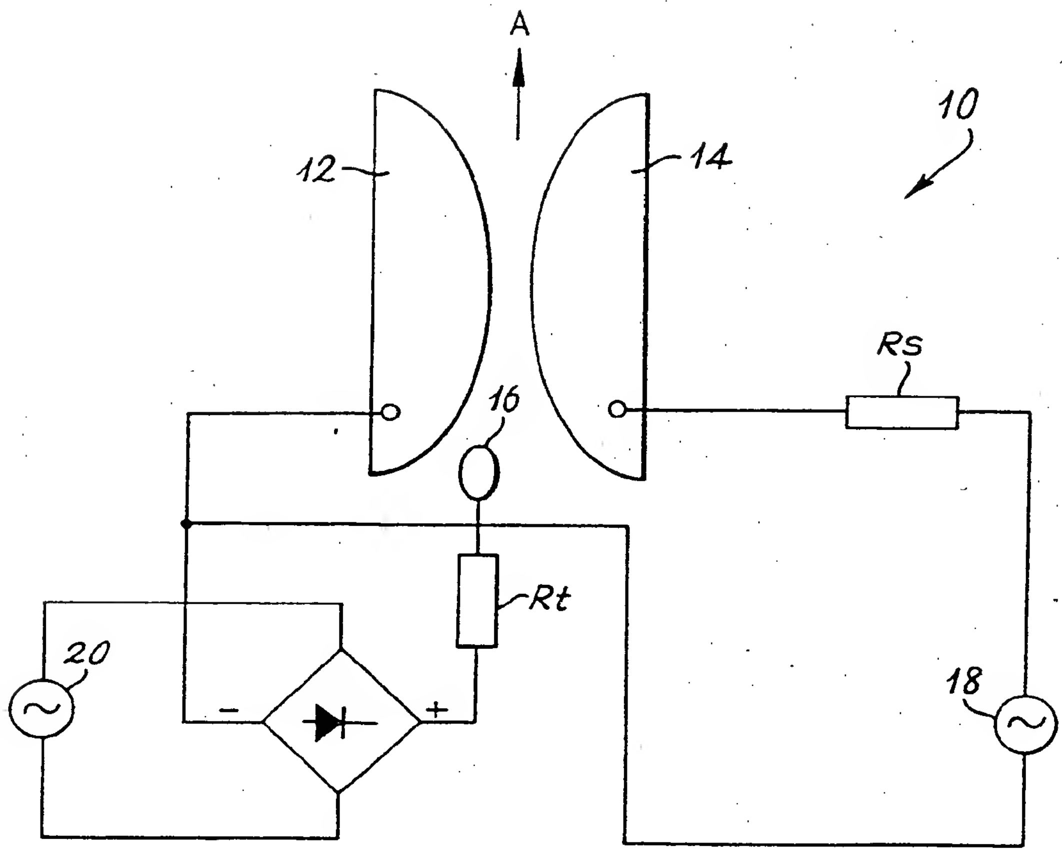


Fig. 1

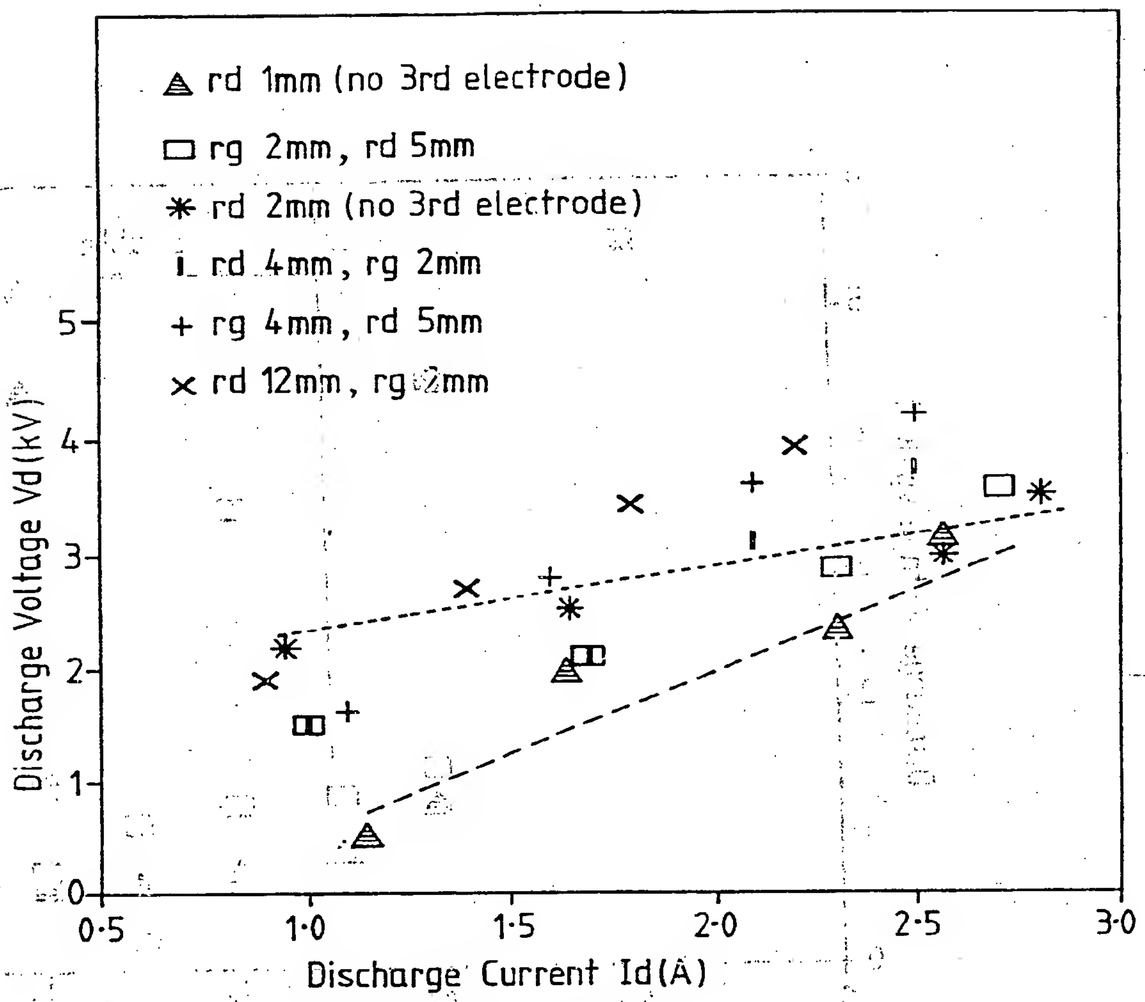

rd 1mm (no 3rd electrode)
rg 2mm, rd 5mm
rd 2mm (no 3rd electrode)
rd 4mm, rg 2mm
rg 4mm, rd 5mm
rd 12mm, rg 2mm
Discharge Voltage Vd(kV)
0
1
2
3
4
5
0·5
1·0
1·5
2·0
2·5
3·0
Discharge Current Id(A)

Fig. 2

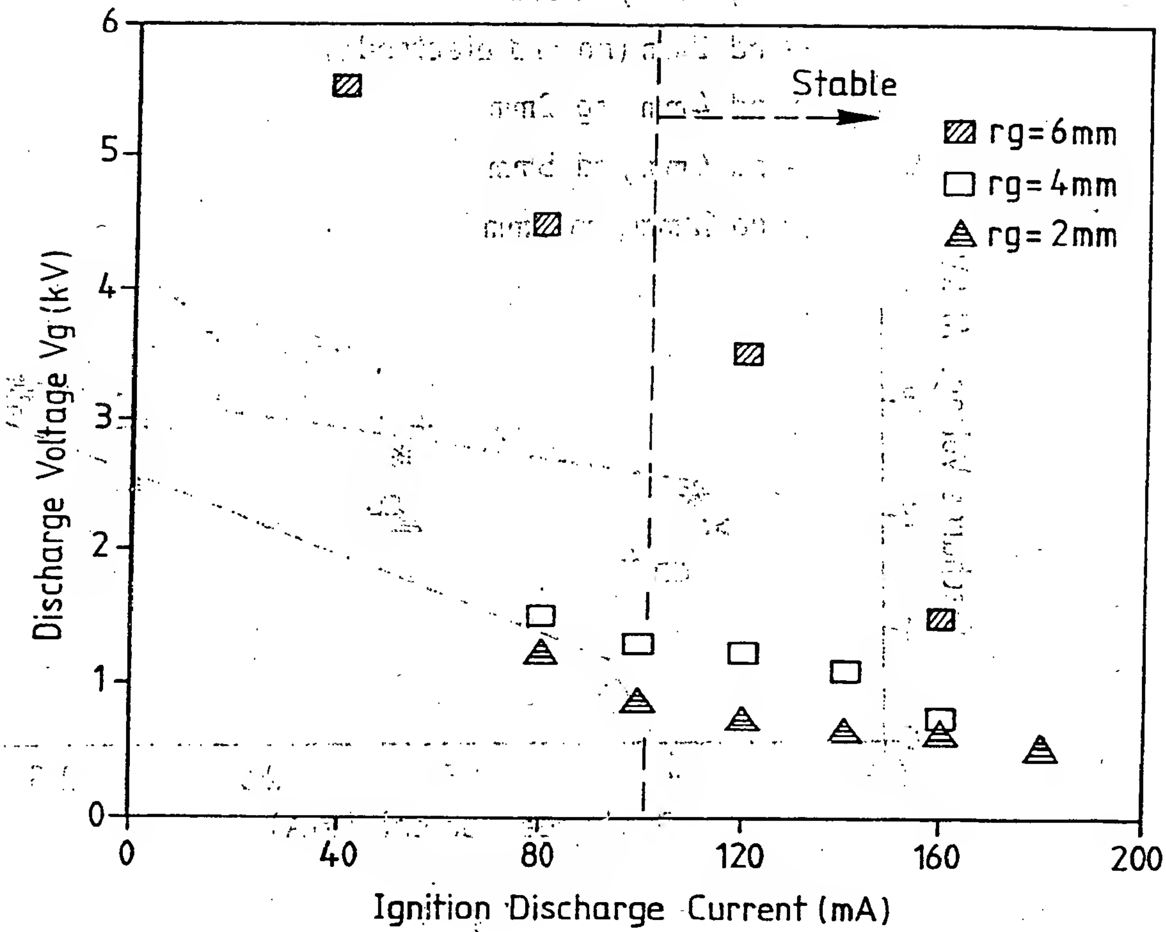

Stable
rg=6mm
rg=4mm
rg= 2mm
Discharge Voltage Vg (kV)
Ignition Discharge Current (mA)
0
1
2
3
4
5
6
40
80
120
160
200

Fig. 3

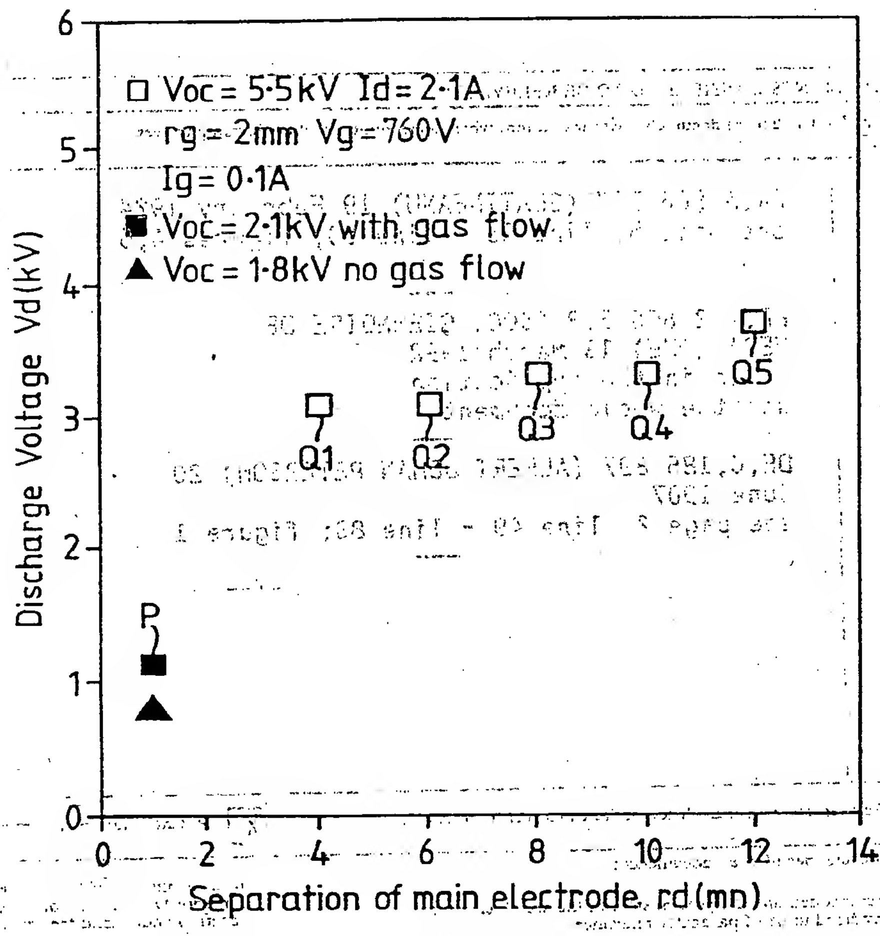

□ Voc = 5·5kV Id = 2·1A
rg = 2mm Vg = 760V
Ig = 0·1A
■ Voc = 2·1kV with gas flow
▲ Voc = 1·8kV no gas flow
Q1
Q2
Q3
Q4
Q5
P
Discharge Voltage Vd(kV)
Separation of main electrode rd(mn)
0
1
2
3
4
5
6
8
10
12
14

Fig.4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 94/01818

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F23G7/06 B01J19/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F23G B01D B01J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR,A,566 707 (SLATINEANU) 19 February 1924 see page 5, line 35 - line 50; figures 4,5	1,3
Y		5,6,9
Y	FR,A,2 666 518 (SOC. GIENNOISE DE MECANIQUE) 13 March 1992 cited in the application see the whole document	5,6,9
A	DE,C,185 897 (ALBERT JOHAN PETERSON) 20 June 1907 see page 2, line 49 - line 83; figure 1	1

-/--

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

2

Date of the actual completion of the international search	Date of mailing of the international search report
23 November 1994	28. 11. 94
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Authorized officer Coli, E

Form PCT/ISA/210 (second sheet) (July 1992)

International Application No
PCT/GB 94/01818

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	DATABASE WPI Week 8423, Derwent Publications Ltd., London, GB; AN 84-144354 & SU,A,1 038 381 (KUNIN) 30 August 1983 see abstract	1
A	EP,A,0 343 987 (MITSUITOATSU CHEMICALS) 29 November 1989	

2

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 94/01818

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
FR-A-566707		NONE		
FR-A-2666518	13-03-92	NONE		
DE-C-185897		NONE		
EP-A-0343987	29-11-89	JP-A-	1297126	30-11-89
		US-A-	4985213	15-01-91